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BIOMASS WITH CARBON REMOVAL AND SUBSOIL STORAGE (BICRS)
A PROMISING NATURE-BASED CO2 REMOVAL METHOD

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SYNOPSIS

An efficient and scalable CO_2 removal method can be realized using biomass from fast growing grasses such as Giant Juncao Grass (GJG) that is harvested, mulched, and injected into the subsoil locally. This method can durably store minimally 80 t CO_2/ha.y in moderate climate areas, and up to 160 t CO_2/ha.y in (sub)tropical regions. The method has a relatively low cost (< 50 Euro/t stored CO_2) and can easily be scaled up to large areas. In addition to CO_2 removal, when established in suitable areas, GJG can enhance degraded land by improving soil ecology, reducing soil erosion, and increasing soil nitrogen and carbon fixation. It can also provide microclimate regulation, act as an ecological barrier whilst knowledge and technology transfer can provide income generation, entrepreneur opportunities, and green jobs. Implementation at scale should consider all these factors as part of sustainable and inclusive development.

1. INTRODUCTION

There is broad consensus that Carbon Dioxide Removal (CDR) or Negative Emission Technologies (NET) will be needed to reach the Paris Agreement goals. The recent **IPCC Synthesis Report**[1] mentions *"Reaching net zero GHG emissions primarily requires deep reductions in CO2, methane, and other GHG emissions, and implies net negative CO2 emissions", "…some hard-to-abate residual GHG emissions (e.g., some emissions from agriculture, aviation, shipping, and industrial processes) remain and would need to be counterbalanced by deployment of CDR methods to achieve net zero CO2 or GHG emissions", "…depending on the context, biological CDR methods like reforestation, improved forest management, soil carbon sequestration, peatland restoration and coastal blue carbon management can enhance biodiversity and ecosystem functions, employment and local livelihoods".*

The recent **World Economic Forum report** concludes:[2]
"CDR is required for three reasons: 1) to compensate for those last 10% of "hard-to-abate" emissions; 2) to draw down Earth's own emissions from natural feedback loops exacerbated by global warming (e.g. forest fires); and 3) to reverse the accumulation of historic emissions."

Graphically, figure 1 illustrates how Negative Emissions help reaching net zero emissions in time:

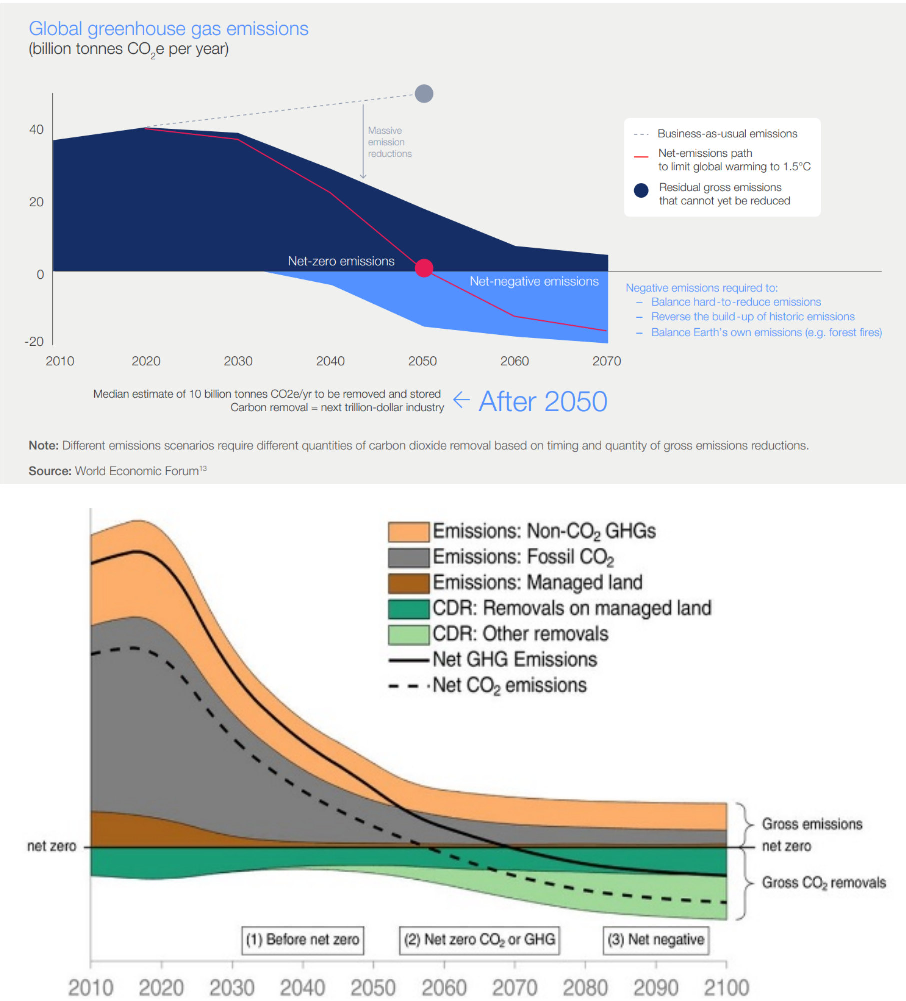

Figure 1. Net negative emissions are needed to reach net zero emissions by 2050 (*WEF and IPCC*)

A new and alternative CDR category of techniques, called Biomass Carbon Dioxide Removal and Storage (BiCRS) has been proposed, as a more efficient alternative for Bio-Energy with Carbon Capture Storage (BECCS), by the Innovation for Cool Earth Forum (ICEF) in 2020, with a significant global 2.5-5.0 $GtCO_2$/y storage potential. One method within this new category proposed by CarbonAlert uses a fast growing grass as the carbon source, as it can capture 100-300 t CO_2/ha.y compared to forests that capture typically less than 10 t CO_2/ha.y.[3] The biomass storage will be achieved through local injection of the biomass slurry directly into the soil at >1.2 m depth. An important aspect regarding the short and long term CO_2 sequestration potential of the proposed method is the prediction and thus quantification of the degree to which the underground stored biomass will be returned back to the atmosphere by emission of CO_2, or other GHG's. While issues related to potential social and ecosystem risks should be taken seriously in the eventual implementation of this approach, it is important to first describe the potential of this method to sequester carbon and what environmental factors will influence this. In the next sections we thus first outline what is known regarding the growing and injecting of the biomass and the expectations of the durability of the CO_2 sequestration.

2. GROWING AND INJECTING THE GIANT JUNCAO GRASS

There is extensive expertise in the cultivation of GJG, a recently emerging crop that has demonstrated its ability to achieve high yields (exceeding 80 t/ha.y dry yield in tropical areas). GJG also exhibits resistance to saline conditions, strong stress tolerance, abundant crude protein, high sugar content and contributes to soil improvement.[4] In addition, certain modified GJG types such as Pennisetum sp. have demonstrated a good capacity for overwintering in non-tropical, moderate climate conditions.[5] Given these positive attributes, injecting the harvested and mulched GJG shoots and stalks directly back into the area where it is cultivated as part of harvesting is a promising new and innovative concept developed by CarbonAlert. Thus far, the injection of wood chips from timber to remove CO_2 and raise ground levels[6] is the only published method which could be seen as comparable. However, since the CO_2 capturing capacity of forests (5-10 t/ha.y) is at least 10 times lower than that of GJG, and there are additional CO_2 emissions involved in the transportation of wood, it is considerably less efficient in terms of sequestration capacity per unit area.

3. RESIDUAL GHG EMISSIONS FROM BURIED/STORED GJG BIOMASS

Given that this is a new approach, it is important to base our estimates for expected behavior on previously established norms and science. One could liken this approach to "building peat" and so looking towards knowledge and studies regarding the behaviour of peat as a model for comparison is reasonable. Further, even though peatland is a different organic matter, Schmidt et al.[7] concluded that environmental composition and conditions determine biomass turnover rather than biomass composition. Therefore, it is reasonable from this perspective to take the well-studied organic matter of peatland, as a model for biomass decomposition and GHG emissions since the conditions are expected to be similar.

CO_2

It has been found that when peatland is in contact with atmospheric weather conditions in a moderate climate it has an average CO_2 emission of 15-20 t/ha. This corresponds to the total CO_2 emissions by peatland in the Netherlands: 4.2 Mt/y for 276.000 ha = 15t/ha (website Staatsbosbeheer). Given that the approach proposed here results in the majority of the volume of biomass to be brought underground (potentially under groundwater levels) the expected CO_2 emissions in practice will be much lower.

Other GHG (CH_4, N_2O)

Generally, the emissions of other GHG's such as CH_4 and N_2O from peatland are much lower than those of CO_2. However, the Global Warming Potential (GWP) of these gases is much higher (25 times for methane, 298 times for N_2O)[8] and so even smaller amounts can lead to significant climate change impacts. Nevertheless, Tiemeyer et al. concluded from measurements that the "CO_2-equivalent" emissions from other GHG such as CH_4 and N_2O are negligible compared to the CO_2 emissions.[9]

4. ESTIMATION OF CO_2 STORAGE CAPACITY

The average *Pennisetum* sp. yield in a temperate region after the second year of growth is 40 t/ha.y, which corresponds to 20t C, or 70t CO_2. This yield plus the 30% biomass found in GJG roots results in 100t/ha CO_2. Maximum losses can be estimated by looking at above mentioned CO_2 and other GHG emissions from peatland. A value of 20t/ha can thus be taken as an upper limit for CO_2 emissions from biomass buried under 1.2 m of soil, where oxygen availability is strongly limited by diffusion. In addition, when injected under groundwater level, it is generally accepted that oxidation is even smaller. As mentioned, CO_2-equivalent emissions from other GHG such as N_2O and CH_4 are found to be lower than CO_2 emissions. Thus, in moderate climates such as Western Europe a CO_2 storage capacity of about 80t CO_2/ha.y can be expected. In tropical areas (average temperature about 10 C higher) a factor of roughly 2 times more yield can be expected, however also twice the losses could be possible. Under these conditions a storage capacity of approximately 160t CO_2/ha.y is thus anticipated. It should be noted, however, that there are large variations due to differences in local subsoil composition and environmental conditions. For this reason, on-site monitoring of yield, root mass, atmospheric CO_2, chlorophyll content and subsoil conditions (pH, redox potential Eh, Rh) is highly recommended in order to certify CO_2 storage amounts and avoid unexpected GHG emissions. In particular Eh has recently been identified as an excellent proxy for biomass oxidation.[10] Finally, the operational emissions resulting from cultivating, harvesting and injecting should be determined using a Life Cycle Analysis (LCA) and subtracted from the stored CO_2-equivalent.

5. CONCLUSION

According to the above rationale and scientific arguments the proposed BiCRS method by CarbonAlert using GJG and local injection >1.2 m under the soil is a promising method for large scale carbon dioxide removal. There are no obvious first-order hurdles preventing the technique from being deployed. Moreover, in order to be considered a viable method for carbon credits this BiCRS method should be validated through modelling and monitoring of several parameters, in particular residual GHG emissions. For the selection of the optimal location to deploy BiCRS, aspects should be considered such as soil composition, local climate, salinity, political stability and possible additional advantages such as desertification prevention and soil uprise. It is important to take notice that the proposed BiCRS method, like similar approaches for carbon sequestration such as biomass crops for bioenergy with carbon dioxide capture and storage or biochar, "can have diverse socio-economic and environmental impacts, including on biodiversity, food and water security, local livelihoods and the rights of Indigenous Peoples, especially if implemented at large scales and where land tenure is insecure".[11] Finally, the World Economic Forum report[2] speaks of hard-needed "*Leadership*", companies need to engage in engineered CDR now, as the world cannot afford to "wait and see"!

DISCLAIMER

The information provided in this whitepaper is for informational purposes only and should not be construed as financial or investment advice. Any scientific advice or projections contained herein are based on our best estimates and assumptions, which may change over time. While every effort has been made to ensure the accuracy and reliability of the information presented in this whitepaper, we make no representations or warranties of any kind, express or implied, about the completeness, accuracy, reliability, suitability, or availability with respect to the content herein. We disclaim any liability for any errors or omissions in the information provided, or for any loss or damage incurred as a result of reliance on the information contained in this whitepaper.

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